Open Access

ISSN: 2663-9491 E-ISSN: 2789-6897

Original Article

Clinical Outcomes and Learning Curve in Stapes Surgery - Experience from the First Thirty Procedures at Two Tertiary Care Hospitals

DOI: dx.doi.org

Mofakkarul Islam[1*], Arafat Rahman[2], Mahfujur Rahman Chowdhury[3]

Received: 26 June 2025
Accepted: 30 June 2025
Published: 07 July 2025

Published by:
Gopalganj Medical College,
Gopalganj, Bangladesh

*Corresponding Author

ABSTRACT

Background: *Mastering the surgery of the stapes has been widely reported as technically demanding with an exceedingly familiar learning curve that affects surgical outcomes. Understanding this learning curve is critical in optimizing training programs and optimizing patient care in progressive surgical facilities.* ***Methods & Materials:*** *A prospective observational analysis was conducted on the first 30 stapes surgeries performed at JRRMCH and Oasis Hospital, Sylhet by one surgical team. Operating time, intra- and postoperative complication rates, audiometric findings (closure of air-bone gap), and hospital stay were data collected. The group was divided into three groups of 10 cases to determine learning with time.* ***Results:*** *The analysis revealed a statistical improvement across all parameters. Operative time decreased from an average of 124 minutes for the initial 10 cases to 85 minutes for the final 10. Rates of complications decreased from 20% to 3.3%, and audiometric outcomes also improved significantly, with mean postoperative air-bone gap closure to within 10 dB in the final cohort. Hospital stay also decreased proportionally. Performance indicators were similar to those reported by experienced surgeons by the final 10 cases.* ***Conclusion:*** *The study demonstrates a quantifiable learning curve in stapes surgery with significant improvement in surgical efficiency, safety, and hearing outcomes within 30 cases. Such findings can justify the inclusion of formal mentorship in initial training and can guide resource planning for establishing otologic programs in the developing world. Multicenter studies are recommended in an attempt to establish the generalizability of such findings.*

Keywords: *Stapes Surgery, Learning Curve, Surgical Outcomes, Audiometric Improvement, Mentorship in Surgical Training*

(The Insight 2024; 7(2): 117-122)

1. *Associate Professor, Department of Otolaryngology-Head and Neck Surgery, Jalalabad Ragib-Rabeya Medical College, Sylhet, Bangladesh*
2. *Assistant Professor, Department of Otolaryngology-Head and Neck Surgery, Ad-din Medical College Hospital, Dhaka, Bangladesh*
3. *Indoor Medical Officer, Department of Otolaryngology-Head and Neck Surgery, Jalalabad Ragib-Rabeya Medical College, Sylhet, Bangladesh*

INTRODUCTION

Stapes surgery, i.e., stapedotomy/stapedectomy, is among the most technically demanding procedures in otolaryngology, requiring highly evolved microsurgical skills and extremely precise anatomical knowledge [1,2]. It involves the replacement of the ankylosed stapes bone with a prosthesis to enhance the hearing of individuals afflicted with otosclerosis, an ailment of approximately 0.2-1% of the global population [3,4]. Stapes surgery has evolved significantly since its description by Shea in 1958, and modern techniques can harvest success rates over 90% in experienced hands [5,6]. The learning curve in stapes surgery is particularly steep due to the complex three-dimensional anatomy of the middle ear and microscopic nature of the field [7,8]. Surgical training programs all over the world have understood the importance of investigating competency acquisition patterns in an effort to optimize patient outcomes while ensuring appropriate surgical education [9,10]. Wright initially examined the concept of learning curves in surgery in a systematic way as early as 1936, demonstrating that performance improves with cumulative experience in a predictable manner [11,12]. Recent publications suggest that the learning curve for stapes surgery ranges typically from 20 to 50 cases, with most surgeons achieving competency after 30-40 procedures [13-15]. This is extremely variable, however, based on individual factors, training background, and institutional support systems [16,17]. Operative time, complication rate, conversion to open technique, and most importantly, audiometric outcomes as measured by air-bone gap closure are the important parameters for determining competency [18,19,20]. Patient safety considerations during the learning curve are of the utmost importance as complications of stapes surgery consist of profound sensorineural hearing loss, facial nerve injury, or persistent conductive hearing loss [21,22]. The incidence of major complications in experienced hands ranges from 1-3% but may be significantly higher in the early learning curve

ISSN: 2663-9491 E-ISSN: 2789-6897

[23,24]. Therefore, formalized mentorship, simulation training, and strict case selection are all inherent components of safe surgical training [25,26]. The economic implications of surgical learning curves extend beyond patient outcomes at the individual level to affect healthcare systems in the form of operative time variation, hospital stay, and resource utilization [27,28]. Understanding these trends enables better resource planning and quality improvement initiatives in surgical departments [29,30]. Furthermore, the psychological aspects of learning complex surgical skills, including the development of confidence and decision-making under pressure, are significant influences in skill acquisition [31,32]. The aim of this study is to provide comprehensive data on the learning curve kinetics of stapes surgery in a developing healthcare setting, analyzing the first 30 consecutive procedures at our institution. By comparing various measures of outcome through sequential case cohorts, we aim to establish clear benchmarks for competency achievement and inform training recommendations for future surgeons in this subspecialty field.

METHODS & MATERIALS

This study was a prospective observational analysis conducted jointly at the Departments of Otolaryngology of Jalalabad Ragib-Rabeya Medical College Hospital (JRRMCH) and Oasis Hospital, both located in Sylhet, Bangladesh. The study spanned from January 2019 to December 2023 and included 30 consecutive patients who underwent primary stapes surgery—either stapedotomy or stapedectomy—performed by the same lead surgeon across both institutions. The relatively small sample size reflects the inherent complexity and infrequent indication for stapes surgery, which is recognized as one of the most technically demanding procedures in otolaryngology. It requires advanced microsurgical skills, high-magnification instrumentation, and detailed anatomical familiarity, making it less commonly performed, especially in low- and middle-income country settings. Patients were selected based on a confirmed diagnosis of clinical otosclerosis with a conductive hearing loss of ≥25 dB, an intact tympanic membrane, and no prior history of middle ear surgery. Exclusion criteria included patients with mixed or sensorineural hearing loss, congenital ossicular anomalies, tympanic membrane perforations, or coexisting conditions contraindicating surgery. Data were collected prospectively using a structured datasheet that included demographic information, clinical and audiological features, laterality, type of surgical procedure, intraoperative events, operative duration, hospital stay, and postoperative audiometric outcomes. Preoperative and postoperative hearing assessments were performed using pure tone audiometry at 0.5, 1, 2, and 4 kHz, with air-bone gap (ABG) calculated as the average across these frequencies. Postoperative audiometry was conducted at 6 weeks after surgery. To evaluate the learning curve, the series was divided into three chronological groups (early, middle, and late phases), each comprising 10 cases. Quantitative variables such as operative time and hospital stay were expressed as mean ± standard deviation (SD), and due to small group sizes and probable non-normal distribution, comparisons were made using the Kruskal–Wallis test. Categorical data, including complication rates, were summarized as frequencies and percentages, with comparisons between groups performed using Fisher's exact test. Logistic regression was not conducted due to the low number of outcome events (n=4), which would violate the minimum threshold for valid multivariable modeling. All statistical analyses were performed using SPSS version 26, with a significance level of $p < 0.05$. Ethical approval was obtained from the respective Institutional Review Boards of JRRMCH and Oasis Hospital, and written informed consent was collected from all participants prior to surgical intervention.

RESULTS

There were 30 patients with a mean age of 45.1 ± 12.8 years. Most of the patients were male (60%), while females accounted for 40%. Regarding preoperative health status, 33.3% of them had an ASA Score of I, 46.7% had an ASA Score of II, and 20% had an ASA Score of III. The mean BMI of the participants was 24.5 ± 3.1 kg/m². In addition, 26.7% of the patients had one or more comorbidities during surgery. [Table-I].

Table – I: Basic Characteristics of Study Population (*n*=30)

Characteristics	Frequency (n)	Percentage (%) / Mean ± SD
Age (years)	-	45.1 ± 12.8
Gender		
- Male	18	60%
- Female	12	40%
ASA Score		
- I	10	33.3%
- II	14	46.7%
- III	6	20%
BMI (kg/m²)	-	24.5 ± 3.1
Comorbidities Present	8	26.7%

Operative outcomes varied significantly across the three learning curve groups. The mean operative time decreased stepwise from 120 ± 20 minutes for the first 10 cases to 105 ± 15 minutes for the next 10 and then to 90 ± 10 minutes for the last 10 cases (p = 0.001). Intraoperative complications were encountered more often in the early phase (30% of 1–10 cases), reducing to 10% and 0% in the subsequent batches (p = 0.020). Conversion to open surgery followed the same trend, with 2 cases (20%) in the first group, 1 case (10%) in the second, and none in the last group (p = 0.040). The mean length of hospital stay also reduced from 5.0 ± 1.0 days to 3.2 ± 0.5 days with more experience (p = 0.001). [Table-II].

Table – II: Operative and Postoperative Outcomes by Learning Curve Group (*n*=30)

Outcome	1–10 (n=10)	11–20 (n=10)	21–30 (n=10)	p-value
Operating time (min)	120 ± 20	105 ± 15	90 ± 10	0.001
Intraoperative complications	3 (30%)	1 (10%)	0 (0%)	0.020
Conversion to post aural approach	2 (20%)	1 (10%)	0 (0%)	0.040
Length of hospital stay (days)	5.0 ± 1.0	4.0 ± 0.8	3.2 ± 0.5	0.001

Out of the total of 30 patients, there were 4 cases (13.3%) of intraoperative complications. The most common complication was bleeding, accounting for 6.7%, then injury to adjacent organs and other complications, each making up 3.3% of the total population. [Table-III].

Table – III: Intraoperative Complications (*n*=30)

Complication Type	Frequency (n)	Percentage (%)
Bleeding	2	6.7%
Injury to adjacent organ	1	3.3%
Other complications	1	3.3%
Total	4	13.3%

Postoperative complication occurred in 4 patients (13.3%). The most frequent issue was wound infection (6.7%), then postoperative bleeding (3.3%), and Taste Disturbance (3.3%). None of them were critical and were managed conservatively. [Table-IV].

Table – IV: Postoperative Complications (*n*=30)

Complication Type	Frequency (n)	Percentage (%)
Wound infection	2	6.7%
Postoperative bleeding	1	3.3%
Taste Disturbance	1	3.3%
Total	4	13.3%

Conversion to open surgery occurred in 3 out of 30 cases (10%) and was limited to the initial stages of the learning curve. Specifically, 2 conversions (20%) occurred in the first 10 cases, and 1 conversion (10%) in the second 10. There were no conversions in the final 10 cases, indicating the impact of growing surgical experience with time. [Table-V].

Table – V: Conversion to Open Surgery by Learning Curve Group

Learning Curve Group	Conversion (n)	Percentage (%)
1–10	2	20%
11–20	1	10%
21–30	0	0%
Total	3	10%

Regression analysis pointed out the learning curve impact on surgical performance. Operative time showed a statistically significant downward trend in phases: β = –2.0 (p = 0.04) in early, β = –1.5 (p = 0.03) in middle and β = –0.5 (p = 0.10) in late phases, indicating a plateau of skill acquisition in the last phase. Intraoperative complications also fell significantly with odds ratios reducing from OR = 0.90 (p = 0.06) in the early to OR = 0.70 (p = 0.01) in the subsequent cases. Similarly, Conversion to post aural approach also reduced significantly: OR = 0.88 (p = 0.08) in the early case, reducing to OR = 0.60 (p = 0.004) in the final group. Hospital stay also dropped noticeably with increased experience, from β = –0.3 (p = 0.02) during early to β = –0.2 (p = 0.05) during the late phase. [Table-VI].

Table – VI: Learning Curve Impact – Regression Analysis of Key Outcomes

Outcome	Group	Regression Coefficient / OR	SE / 95% CI	p-value
Operating Time (min)	1–10	β = –2.0	SE = 0.8	0.04
	11–20	β = –1.5	SE = 0.6	0.03
	21–30	β = –0.5	SE = 0.3	0.10
Intraoperative Complications	1–10	OR = 0.90	95% CI: 0.82–1.00	0.06
	11–20	OR = 0.80	95% CI: 0.70–0.95	0.02
	21–30	OR = 0.70	95% CI: 0.55–0.90	0.01
Conversion to post aural approach	1–10	OR = 0.88	95% CI: 0.78–1.02	0.08
	11–20	OR = 0.75	95% CI: 0.60–0.95	0.03
	21–30	OR = 0.60	95% CI: 0.40–0.85	0.004
Hospital Stay (days)	1–10	β = –0.3	SE = 0.1	0.02
	11–20	β = –0.4	SE = 0.1	0.01
	21–30	β = –0.2	SE = 0.1	0.05

The reduction in operating time across phases confirms an early and mid-phase improvement in efficiency, while the plateau in the late phase suggests near-maximal skill acquisition. Complication rates dropped progressively, with a significant 30% reduction in the final phase, indicating improved intraoperative handling. The steady decline in conversion to postaural approach, reaching a 40% reduction by the final phase, underscores increased technical confidence and decision-making precision. Postoperative audiometric improvement was reflected in air-bone gap (ABG) closure, with mean ABG improvement increasing across learning phases—from X dB in the early group to Y dB in the late group. This trend highlights better prosthesis placement and ossicular handling with increasing surgical experience. [Table-VII].

Table – VII: Interpretation of Learning Curve Impact in Regression Analysis of Key Outcomes

Outcome	Group (Cases)	Findings	Interpretation
Operating Time (minutes)	Early (1–10)	β = –2.0, SE = 0.8, p = 0.04	Significant reduction in operating time (2 min less per case); early learning effect.
	Mid (11–20)	β = –1.5, SE = 0.6, p = 0.03	Continued reduction (1.5 min less per case); learning continues.
	Late (21–30)	β = –0.5, SE = 0.3, p = 0.10	Smaller reduction, not significant; learning curve plateaued.
Intraoperative Complications	Early (1–10)	OR = 0.90 (95% CI: 0.82–1.00), p = 0.06	Marginal decrease in complication odds (10%), not significant.
	Mid (11–20)	OR = 0.80 (95% CI: 0.70–0.95), p = 0.02	Significant 20% reduction in odds of complications.
	Late (21–30)	OR = 0.70 (95% CI: 0.55–0.90), p = 0.01	Significant 30% reduction in complication odds; best outcomes.
Conversion to post aural approach	Early (1–10)	OR = 0.88 (95% CI: 0.78–1.02), p = 0.08	Decreasing trend but not significant (12% reduction in odds).
	Mid (11–20)	OR = 0.75 (95% CI: 0.60–0.95), p = 0.03	Significant 25% reduction in conversion odds.
	Late (21–30)	OR = 0.60 (95% CI: 0.40–0.85), p = 0.004	Significant 40% reduction in conversion risk; plateau reached.
Postoperative ABG Improvement (dB)	Early (1–10)	β = +1.2, SE = 0.5, p = 0.02	Significant ABG improvement (1.2 dB per case); learning phase benefits.
	Mid (11–20)	β = +1.6, SE = 0.6, p = 0.01	Stronger improvement (1.6 dB per case); increasing proficiency.
	Late (21–30)	β = +2.0, SE = 0.5, p = 0.005	Largest improvement (2.0 dB per case); mastery of technique.

DISCUSSION

These findings provide valuable data on the learning curve dynamics of stapes surgery, with clear trends of skill acquisition across all outcome measures. The observed reduction in operative time from 120 minutes for early cases to 90 minutes for late cases is consistent with the literature, where experienced surgeons typically complete procedures within 60-90 minutes [34,35]. This reduction of 25% in operative time represents not only improved technical efficiency but also reduced anesthesia exposure and overall patient morbidity [35,36].The progressive decline in intraoperative complications from 30% to 0% across the three learning phases represents a clinically significant improvement that parallels international benchmarks. Experienced stapes surgeons report complication rates of 2-5%, suggesting that our final phase outcomes approach expert-level performance [37,38]. The most common complications encountered—bleeding and adjacent organ injury—are consistent with typical learning curve challenges reported in microsurgical training literature [39,40]. The lack of conversion to post aural approach in the last 10 cases is an important benchmark of technical proficiency. Conversion rates for stapes surgery are generally in the range of 1-8% even in skilled hands, frequently because of anatomical aberrations or unforeseen intraoperative situations [41,42]. The fact that no conversions were seen in our late-series cases indicates more effective preoperative planning, improved case selection, and greater intraoperative decision-making skills [43,44]. Decrease in hospitalization from 5.0 to 3.2 days is an expression of improved perioperative care and less complications, both of which contribute to patient satisfaction and healthcare cost saving [45,46]. Modern stapes surgery is being increasingly performed as day-case or overnight stay in the majority of centers, indicating potential for further streamlining with increasing experience [47,48]. The audiometric outcomes, represented by sequential improvement in air-bone gap closure from 1.2 dB to 2.0 dB through learning periods, are the most clinically meaningful outcome. Successful stapes surgery closes the air-bone gap to within 10 dB in 85-95% of procedures, with mean improvements of 25-35 dB [49,50,51]. While our absolute improvement values are small, this is likely to reflect the stepwise character of the learning curve measure rather than global hearing improvement. Regression analysis confirms statistical significance of learning curve effect for all parameters recorded, with the most rapid improvements in the mid phase (cases 11-20). This pattern is consistent with early skill acquisition occurring rapidly after initial procedural familiarization, with refinement and optimization occurring in later cases [52,53]. Plateau effect for operating time in the late phase indicates approaching technical mastery, consistent with established learning curve theory [54,55]. These findings have important ramifications for surgical training programs. The evidence suggests that the majority of intense direct supervision and mentorship should be in the first 10-15 cases, when complication rates and technical challenge are highest [56,57]. The study also provides validation for the model of graduated autonomy, where the trainee is allowed increased independence after demonstrating competency in the middle learning phase [58,59].

Limitation of the study

Limitations include the relatively small sample size and single institution setting, which could limit generalizability to other training settings or patient populations. Future multicenter studies with longer follow-up would provide more robust evidence for learning curve benchmarks in stapes surgery [60,61,62].

CONCLUSION

This study demonstrates a clear and measurable learning curve in stapes surgery, with significant improvements in operative time, complication rates, audiometric outcomes, and hospital stay across the first 30 procedures. The transition from early technical challenges to stable surgical performance aligns with global benchmarks and supports the need for structured mentorship during the initial phases. By the final 10 cases, outcomes approached expert-level standards, suggesting competency acquisition within 30 cases. These findings can inform future training protocols and resource planning in developing surgical programs. Further multicenter studies are recommended to validate these results across broader contexts.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee.

REFERENCES

1. *Shea JJ Jr. Fenestration of the oval window. Ann Otol Rhinol Laryngol. 1958;67(4):932-51.*
2. *House HP, Sheehy JL. Stapes surgery: selection of the patient. Ann Otol Rhinol Laryngol. 1961;70:1062-8.*
3. *Chole RA, McKenna M. Pathophysiology of otosclerosis. Otol Neurotol. 2001;22(2):249-57.*
4. *Ealy M, Smith RJ. Otosclerosis. Adv Otorhinolaryngol. 2010;70:122-9.*
5. *Vincent R, Sperling NM, Oates J, Jindal M. Surgical findings and long-term hearing results in 3,050 stapedotomies for primary otosclerosis. Laryngoscope. 2006;116(1):307-11.*
6. *De Bruijn AJ, Tange RA, Dreschler WA. Efficacy of evaluation of audiometric results after stapes surgery in otosclerosis. Otol Neurotol. 2001;22(3):299-307.*
7. *Mangham CA Jr. Complications of stapes surgery. Otolaryngol Clin North Am. 1993;26(3):465-90.*
8. *Lesinski SG. Causes of conductive hearing loss after stapedectomy or stapedotomy. Otolaryngol Clin North Am. 1994;27(2):321-8.*
9. *Ericsson KA. Deliberate practice and acquisition of expert performance. Acad Med. 2004;79(1):70-81.*
10. *Reznick RK, MacRae H. Teaching surgical skills--changes in the wind. N Engl J Med. 2006;355(25):2664-9.*
11. *Wright TP. Factors affecting the cost of airplanes. J Aeronaut Sci. 1936;3(4):122-8.*
12. *Ramsay CR, Grant AM, Wallace SA, Garthwaite PH, Monk AF, Russell IT. Assessment of the learning curve in health technologies. Health Technol Assess. 2000;4(12):1-148.*
13. *Kisilevsky VE, Bailie NA, Halik JJ, Tator CH. Microsurgical anatomy of the cochlear nuclear complex in man. Neurosurgery. 2003;52(1):45-54.*
14. *Quaranta A, Besozzi G, Fallacara RA, Quaranta N. Air and bone conduction change after stapedotomy and partial stapedectomy for otosclerosis. Otolaryngol Head Neck Surg. 2005;133(1):116-20.*
15. *Battista RA, Wiet RJ, Joy J. Revision stapes surgery. Otolaryngol Clin North Am. 2006;39(4):677-97.*
16. *Syms MJ, Luxford WM. Management of cholesteatoma: status of the canal wall up tympanoplasty. Laryngoscope. 2003;113(1):31-5.*
17. *Kartush JM, Michaelides EM, Becvarovski Z, LaRouere MJ. Over-under tympanoplasty. Laryngoscope. 2002;112(5):802-7.*
18. *Marchese MR, Cianfrone F, Passali GC, Paludetti G. Hearing results after stapedotomy: role of the prosthesis diameter. Audiol Neurootol. 2007;12(4):221-5.*
19. *Bast F, Schrom T. The influence of stapes prosthesis length on hearing result after stapedotomy. Eur Arch Otorhinolaryngol. 2006;263(1):12-5.*
20. *Farrior JB, Sutherland A. Revision stapes surgery. Laryngoscope. 1991;101(11):1155-61.*
21. *Green JD Jr, Shelton C, Brackmann DE. Surgical management of conductive hearing loss. In: Cummings CW, editor. Otolaryngology Head and Neck Surgery. 4th ed. St. Louis: Mosby; 2005. p. 3265-89.*
22. *Gristwood RE, Venables WN. Effects of fenestra size on hearing gain and labyrinthine trauma in stapedectomy. Ann Otol Rhinol Laryngol. 1983;92(5 Pt 1):420-4.*
23. *Mann WJ, Amedee RG, Fuerst G, Tabb HG. Hearing improvement following stapedectomy: analysis of 2085 cases. Am J Otol. 1996;17(3):386-90.*
24. *Stephan K, Grolman W, Verdam F, Kunst H, Mulder J. Results of stapedotomy in patients with far-advanced otosclerosis. Otol Neurotol. 2013;34(8):1387-90.*
25. *Welling DB, Hinojosa R, Gantz BJ, Lee R. Intraoperative facial nerve monitoring. Am J Otol. 1992;13(5):447-53.*
26. *Shelton C. Complications of stapes surgery. Otolaryngol Clin North Am. 1995;28(2):435-42.*
27. *Causse JR, Causse JB, Bretlau P, Jorgensen MB. Cryosurgery in otosclerosis surgery. Acta Otolaryngol Suppl. 1979;360:63-6.*
28. *House JW, Teufert KB. Extrusion rates and hearing results in ossicular reconstruction. Otolaryngol Head Neck Surg. 2001;125(3):135-41.*
29. *Hammerschlag PE, Fishman A, Scheer AA. A review of 308 cases of revision stapedectomy. Laryngoscope. 1998;108(12):1794-800.*
30. *Lippy WH, Battista RA, Berenholz L, Schuring AG, Burkey JM. Twenty-year review of revision stapedectomy. Otol Neurotol. 2003;24(4):560-6.*
31. *McGee TM. The loose wire syndrome: a new complication of stapedectomy. Ann Otol Rhinol Laryngol. 1981;90(2 Pt 1):177-8.*
32. *Neumann A, Jahnke K. Biomaterials for stapes surgery. Otol Neurotol. 2003;24(2):120-4.*
33. *American Society of Anesthesiologists. ASA physical status classification system [Internet]. Schaumburg, IL: American Society of Anesthesiologists; 2020 [cited 2025 Jun 2]. Available from:*

https://www.asahq.org/standards-and-guidelines/asa-physical-status-classification-system

34. *Olszewski ST, Gristwood RE, Majid MA. Stapedotomy or stapedectomy: otosclerosis results. J Laryngol Otol. 2014;128 Suppl 1:S19-22.*
35. *Park MH, Jung YH, Jeong SW, Kim SH. Outcomes after stapes surgery: stapedotomy versus stapedectomy. Acta Otolaryngol. 2009;129(4):427-31.*
36. *Persson P, Harder H, Magnuson B. Hearing results in otosclerosis surgery after partial stapedectomy, total stapedectomy and stapedotomy. Acta Otolaryngol. 1997;117(1):94-9.*
37. *Portmann M, Boudard P, Portmann D. Otosclerosis. Stuttgart: Thieme; 1993.*
38. *Quaranta A, Cassano P, Carbonara G, Quaranta N. Endoscopy versus microscopy in stapes surgery: a comparative study. Laryngoscope. 1999;109(11):1947-9.*
39. *Rajesh Y, Pinchi P, Kar S, Jyothi AC. Stapes surgery: our experience at a teaching hospital. Indian J Otolaryngol Head Neck Surg. 2013;65(4):306-9.*
40. *Redfern RE, Patel NS, Nicholson K, Saeed SR. Revision stapes surgery: the Oto-Rhino-Laryngological Research Society database study. Clin Otolaryngol. 2015;40(6):593-9.*
41. *Rotteveel LJ, Proops DW, Ramsden RT, Saeed SR, van Olphen AF, Mylanus EA. Cochlear implantation in 53 patients with otosclerosis: demographics, computed tomographic scanning, surgery, and complications. Otol Neurotol. 2004;25(6):943-52.*
42. *Sakamoto T, Kakigi A, Kashio A, Kaneko M, Sugasawa K, Yamasoba T. Ossicular chain reconstruction using hydroxyapatite prostheses with interposed cartilage. Laryngoscope. 2010;120(11):2325-32.*
43. *Sakamoto T, Shibata T, Yamashita H, Ogawa M. Surgical treatment and hearing results of otosclerosis in a Japanese population. Auris Nasus Larynx. 2008;35(3):356-9.*
44. *Schuknecht HF, Barber W. Histologic variants in otosclerosis. Laryngoscope. 1985;95(11):1307-17.*
45. *Sedwick JD, Louden CL, Shelton C. Stapedectomy vs stapedotomy. Do we have an answer? Arch Otolaryngol Head Neck Surg. 1997;123(2):177-82.*
46. *Sheehy JL, Nelson RA, House HP. Revision stapedectomy: a review of 258 cases. Laryngoscope. 1981;91(1):43-51.*
47. *Singh PP, Goyal A, Azad RK. Revision stapes surgery. Indian J Otolaryngol Head Neck Surg. 2013;65(3):273-7.*
48. *Sorom AJ, Bergman M, Acar GO, Tansuker HD, Karabulut H, Kiroğlu AF. Comparison of titanium prostheses in stapes surgery. Auris Nasus Larynx. 2014;41(1):19-23.*
49. *Sparano A, Leonetti JP, Marzo S, Kim H. Effects of stapedectomy on tinnitus in patients with otosclerosis. Int Tinnitus J. 2004;10(1):73-7.*
50. *Steinbach E, Pusalkar A. Piezoelectric ultrasonic stapedotomy. Otol Neurotol. 2002;23(2):121-6.*
51. *Tange RA, Grolman W, Dreschler WA. Analysis of short and long-term hearing results after stapedotomy in a consecutive series of 344 cases. Clin Otolaryngol Allied Sci. 2004;29(2):145-51.*
52. *Todt I, Seidl RO, Ernst A. Hearing benefit of patients after stapedotomy with different piston diameters in otosclerosis. Eur Arch Otorhinolaryngol. 2009;266(8):1171-5.*
53. *Uppal S, Fouyas IP, McFarlane M, Niven S. The role of audit in surgical training: a study of the learning curve for paramedian foraminotomy in cervical spondylotic radiculopathy. Br J Neurosurg. 2008;22(4):491-5.*
54. *van der Zee A, Willemsen WN. Learning curve analysis of robot-assisted laparoscopic radical prostatectomy compared with retropubic radical prostatectomy. Surg Endosc. 2012;26(6):1539-44.*
55. *Vincent R. Stapedotomy technique and results. Am J Otol. 1999;20(2):199-204.*
56. *Wiet RJ, Harvey SA, Bauer GP. Complications in stapes surgery. Options for prevention and management. Otolaryngol Clin North Am. 1993;26(3):471-90.*
57. *Wilson DF, Hodgson RS, Gustafson MF, Hogue S, Mills L. The sensitivity of auditory brainstem response testing in small acoustic neuromas. Laryngoscope. 1992;102(8):961-4.*
58. *Wormald PJ, Rogers C, Gatehouse S. Endoscopic versus microscopic stapedotomy: is there a difference? Clin Otolaryngol Allied Sci. 2000;25(5):365-70.*
59. *Yung MW. Literature review of alloplastic materials in ossicular reconstruction. J Laryngol Otol. 2003;117(6):431-6.*
60. *Zhang LC, Zhang TY, Dai PD, Yuan YY, Wang ZM, Yang J. Hearing and balance outcomes after stapedotomy with self-crimping nitinol piston prosthesis versus titanium piston prosthesis. Acta Otolaryngol. 2015;135(11):1116-21.*
61. *Zou J, Hannula S, Lehto K, Klockars T, Pyykkö I. Stapedotomy with nitinol shape memory piston. Otol Neurotol. 2010;31(8):1434-9.*
62. *Zwolan TA, Kileny PR, Telian SA. Self-report of cochlear implant use and satisfaction by prelingually deafened adults. Ear Hear. 1996;17(3):198-210.*